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ENERGY MANAGEMENT DIVISION

B.C. Hydro

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PROJECT 8405

ENERGY AND ECONOMIC CONSIDERATIONS FOR THE SELECTION OF LUMBER DRYING ALTERNATIVES

SYNOPSIS

The results of this report indicate that lumber drying with dehumidification type kilns is the best system for many lumber production applications, particularly those associated with remanufacturing and value added operations. The increased use of heat pump dehumidifier kilns could produce additional electric revenue to B. C. Hydro in the order of $20 million/year within five years.

PROJECT

Initiated/Requested by:	G.D.A. Henriques/P. R. Willis
Date Completed:	19 June 1985
Completed by:	P. R. Willis, P.Eng.
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ENERGY USE ENGINEERING DEPARTMENT

PROJECT SUMMARY

PROJECT No. 8405 PRIORITY 3 (ASAP)

TITLE: Energy and Economic Considerations for the Selection of Lumber Drying Alternatives

INITIATED/REQUESTED BY: P. R. Willis/G.D.A. Henriques

ASSIGNED TO: P. R. Willis ASSIGNED BY: G.D.A. Henriques

DATE ASSIGNED: 23 May 1984 DATE REQUIRED: 30 September 1984

ESTIMATED COMPLETION: August 1984 COMPLETED:

OBJECTIVES AND NOTES:

To compare the economics and energy requirements of the different drying kiln alternatives.

- Review literature on drying kilns.
- Obtain operating data on the three main kiln types.
- Discuss with kiln suppliers design criteria.
- Perform cost and energy balance calculations on the three alternatives.
- Write report on information obtained and calculations performed.

For each of the alternatives, the report would contain:

- energy balance calculations
- estimated operating manpower requirements
- estimated capital costs
- comments from the literature and kiln users as to the:
  - quality of drying
  - maintenance requirements and
  - reliability.

COPIES TO: DEPARTMENT MANAGER (THEN RECORD FILE), BLUE FILE, SUPERVISOR, P. R. Willis, C. F. Mason, T. J. Newton, C. B. Guelke, EUE Supervisors, R. Van Schilt, C. C. Purves

PLEASE ADVISE AS SOON AS POSSIBLE IF CHANGES ARE REQUIRED ABOVE

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1.0 SUMMARY

The results of this report indicate that drying lumber with electrically powered dehumidification type kilns is an attractive alternative for many applications, compared to hot air kilns using oil, butane, propane, natural gas, and wood waste. Comparative costs for drying western hemlock clears are shown on Figure 1.

Drying kilns in B. C. consume approximately 11 million GJ/year of energy. A 1979 survey by Forintek Canada Incorporated gave the following breakdown for the fuel source for this energy:

Natural Gas	66.7%
Propane	5.6%
Butane	3.6%
Wood Waste	22.5%
Oil	1.5%

Since this report was prepared, the wood waste percentage has increased somewhat, the natural gas share has diminished and a few electric dehumidifier kilns have been placed in service.

In discussions with the Council of Forest Industries, the two main reasons why more dehumidification type units are not being used is because:

- the industry is not fully aware of the economic and operating benefits of this new technology;
- companies are reluctant to make capital expenditures in the present economic climate.

Most of the gas fired kilns are not in B. C. Hydro's gas service areas. For instance, of the 200 natural gas fired kilns in the province, approximately 40 are served by B. C. Hydro gas.

Comparison tests co-sponsored by B. C. Hydro, COFI, and Forintek between a gas fired hot air kiln and a dehumidification kiln showed that the energy requirement for the dehumidification kiln was 40% of the requirement for the gas fired kiln resulting in comparable energy costs at current electric and gas rates.

For hot air kilns using butane, propane or #2 oil, the energy cost for the dehumidification process would be much less. A hot air kiln using wood waste has the lowest energy cost but the equipment capital cost makes it prohibitive for small systems and, to a certain extent, offsets the energy cost advantage on large systems.

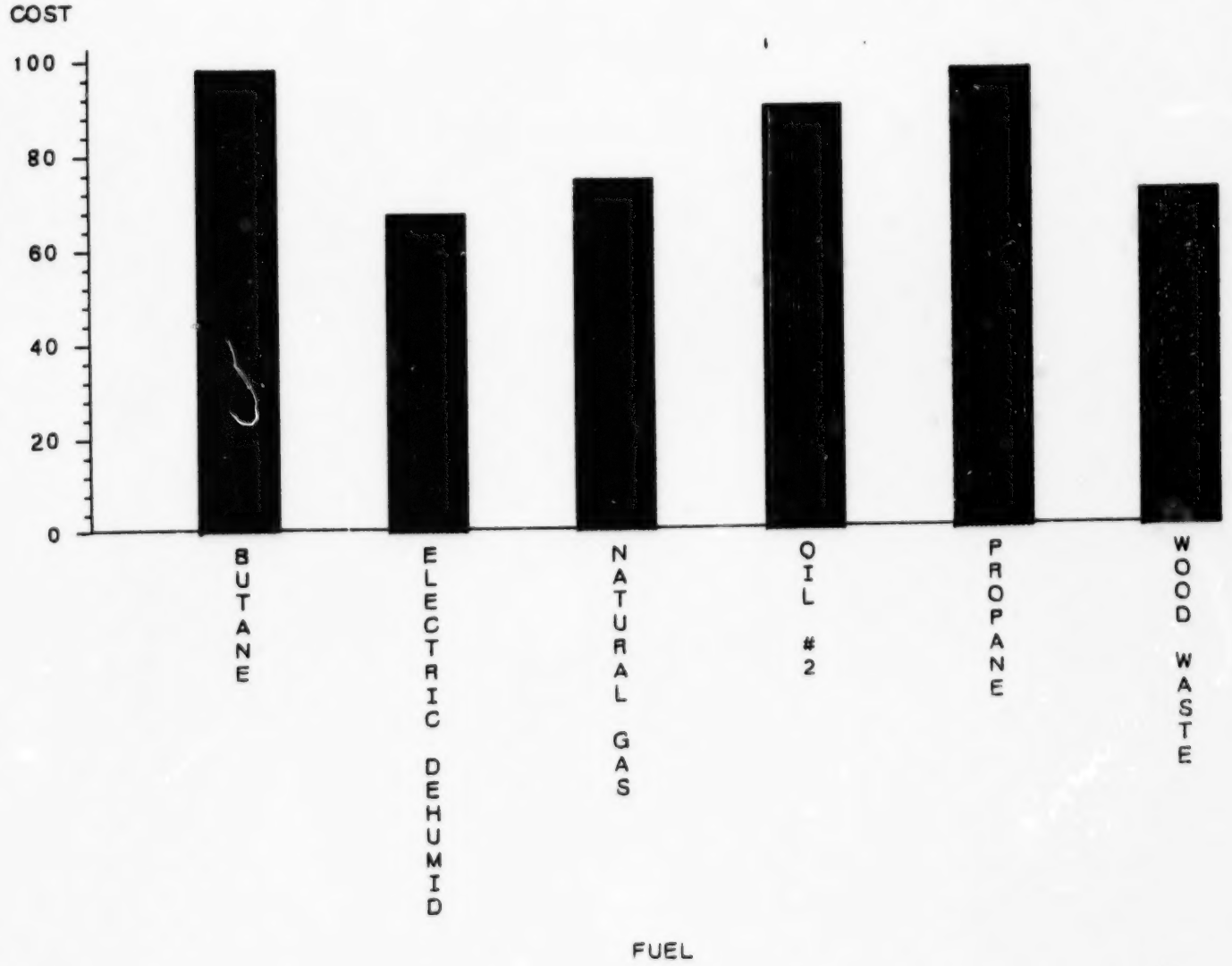
A major consideration in comparing drying alternatives is the degree of lumber damage (degrade) that occurs during the process. This damage occurs as obvious defects (checks, splits, etc.) or as internal stresses which cause problems during later stages of manufacture. In the comparison test mentioned above, the dehumidification dried lumber contained far less internal stress than the gas fired kiln lumber. It appears, in general, that one

of the major advantages to dehumidification drying is a significant reduction in the amount of degrade.

The increased use of dehumidification drying represents an estimated annual electric revenue to B. C. Hydro of approximately $20 million. It would not have an impact on our gas sales because the dehumidification kilns would be either new kilns to be used for lumber that is not presently being dried or as a replacement of existing hot air kilns in the interior. This potential market would consist of:

- 50% of the propane, butane and oil fired kilns replaced with dehumidification units (all of these units are in regions where gas is not available);
- an increase in the drying of western hemlock to suit new markets;
- 20% of the construction lumber being dried with dehumidifier kilns (most of the gas kilns replaced would be in the interior).

The major disadvantage to the dehumidification process is the drying time which is much longer than with conventional hot air kilns. However, there are indications that this drying time could be substantially reduced. A CEA project involving the building of a demonstration kiln at Forintek is specifically going to address this problem. A description of this project is included in Appendix II. Also, the economics are such that longer drying times do not completely offset the energy savings and the increased drying quality obtained.



Dollars Per Mfbm

IR50.2

FIGURE 1 - COMPARATIVE COSTS FOR DRYING WESTERN HEMLOCK CLEARS - LARGE SIZE PLANT

2.0 INTRODUCTION

Drying kilns in B. C. are a large energy consumer, requiring approximately 11 million GJ/year. It appears that there are going to be some major changes in the type of kilns utilized and this could have a significant impact on gas and electricity usage.

The objectives of this report were to compare the economics, energy consumption and degrade (lumber damaged from drying operation) of the different drying alternatives.

The methodology used was:

- review literature on drying kilns;
- obtain operating data on the three main kiln types;
- discuss with kiln suppliers design criteria;
- perform cost and energy balance calculations on the three main alternatives.

A major part of this project involved working with COFI (Council of Forest Industries) and Forintek to conduct some comparison tests, using a dehumidifier kiln in Victoria and a gas fired kiln in Surrey. COFI and Forintek performed the majority of the actual test work while B. C. Hydro financed transportation costs and the installation of some metering.

Dried lumber can be broken into two broad categories - dimension lumber and clears. The dimension lumber is construction grade material while clears is quality lumber that is mainly used for remanufacturing (moulding stock, panelling, furniture, etc.).

The economics for drying lumber are completely different for each of these categories. This report deals mainly with the clears category and specifically with the western hemlock species because it appears that the dehumidification process is the most suitable for this application. A much more exhaustive economic comparison will be performed in the current CEA Project 418U461, reference 5.

3.0 SYNOPSIS OF LUMBER INDUSTRY PRODUCTION STATISTICS

The average annual lumber production in British Columbia from 1978 to 1983 was 27.6 million cubic metres (11.7 billion ft.b.m.). Over the same period, the annual sales were $2.4 billion giving an average value of $87 per cubic metre ($205 per thousand board feet). Sawmills utilize approximately 57 kW.h of electrical energy per cubic metre of lumber produced and 0.7 GJ per cubic metre of lumber dried. Table 1 is a summary of pertinent B. C. lumber production statistics.

TABLE 1 - Lumber Drying in B. C.

	Interior	Coast	Total
Percentage Lumber Kiln Dried	80	5	
Average Electrical Energy Consumption kW.h/m³			57
Average Gas Energy Used For Dried Lumber GJ/m³			.7
No. Mills	209	111	320
* No. of Kilns	300	110	410
* No. of Kilns Gas Fired			200**
* No. of Kilns Fired With Wood Waste			160
No. of Kilns Fired With Butane, Propane or Oil			38
* No. of Dehumidifier Kilns			12
B. C. Hydro Electricity Sales to Industry (12 months ending June 1984)			1,350 GW.h
B. C. Hydro Gas Sales to Industry (12 months ending June 1984)			831 TJ

EUE B. C. Hydro
PRW/85/05/24

* This data is based on a 1979 Forintec survey and discussions with manufacturers and is not completely up to date.

** Of the 200 natural gas fired kilns in the province, approximately 40 are served by B. C. Hydro gas.

4.0 DRYING FUNDAMENTALS

4.1 Reasons for Drying

The moisture content (mc) of a standing tree ranges from about 35% (on a dry basis) in the heartwood of some softwood species to about 200% in the sapwood of some species (i.e. 66%

moisture on a greenwood basis). There are many advantages to drying before placing lumber in service. Some of these are:

(a) To provide a dimensionally stable material which can be cut or turned to exact dimensions. Wood will swell or shrink with changes in its mc. If it can be dried to the mc it will ultimately attain in use, and is then placed in a reasonably stable environment, further changes in dimensions will be imperceptible.

(b) To eliminate warping, splitting and checking of products in use. When wood dries, the outer surfaces dry first, resulting in surface shrinkage and drying stresses. If these stresses exceed the strength of the wood, it may check and split.

(c) To render wood less subject to biological stain, decay or insect attack. Biological stains and decays are caused by the growth of fungi which use wood or its contents as food. Wood at less than about 22% mc is immune to fungal attack.

(d) To prepare for further treatment. Wood must be dried to suitable mc's for gluing and for impregnation treatments. For glued-laminated timbers, the mc should be about 11% and, for the gluing of softwood plywood, 3 to 4%.

(e) To reduce the weight of lumber and thereby minimize shipping and handling costs. Shipping charges for lumber transported by rail or truck are based on shipping weight. There is, therefore, a direct economic benefit in shipping dry lumber. Traditionally, this has been the prime reason for drying softwood dimension construction lumber in areas serviced by railways.

4.2 Grades and Standards

As a result of the benefits accruing to consumers in the use of properly dried lumber, various specifying organizations have defined dried lumber in two categories. The first category is dimension lumber. Dimension lumber is considered dry if the mc is below 19% and green if it is above 19%.

Clears, selects, factory lumber and moulding stock less than 2 inches thick make up the second category and must be dried to a mutually agreed upon maximum mc, usually from 8 to 12% depending on user requirements.

4.3 Moisture Definitions

Figure 2 shows the cross section of a tree showing various wood zones.

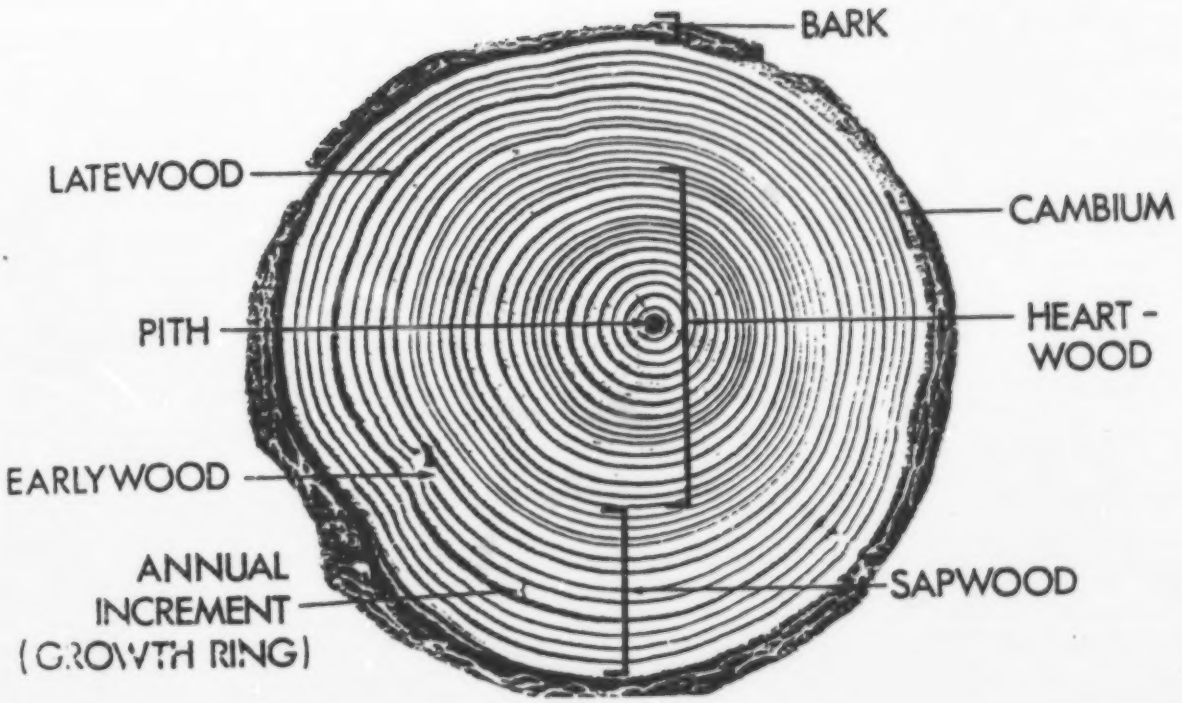


Figure 2 - Wood Zones in Tree Cross Sections

Since one of its major functions is water conduction, sapwood normally contains large quantities of water, even after a tree is felled. In hardwoods and certain softwood species, heartwood also retains large quantities of water. In other softwoods, heartwood is characterized by its relatively low moisture content (mc). Moisture in wood occurs in three forms:

1. as free water in cell cavities;
2. as vapor in the air in the part of cell cavities not occupied by liquid; and
3. as hygroscopic or bound water, absorbed primarily on the cellulose and hemicellulose molecules which constitute the greater part of wood substance.

For wood and wood products, the moisture content is defined as the weight of water contained in the wood, expressed as a percentage of the weight of ovendry wood. It can be calculated as the difference between the green and dry weights, divided by the dry weight, and multiplied by 100%.

$$mc = \frac{W_G - W_D}{W_D} \times 100\% = \frac{W_W}{W_D} \times 100\%$$

where: mc = moisture content
W_W = weight of water
W_D = ovendry weight of wood
W_G = green weight of wood

The fibre saturation point (fsp) is defined as the mc at which cell walls are saturated with bound water, but no free water exists in cell cavities. The fsp varies with species and is usually between 23 and 34%.

Equilibrium moisture content (emc) is the term used to define the mc of wood which has been exposed to the same conditions of temperature and humidity for a sufficiently long period to reach equilibrium. A change in temperature or humidity will result in a corresponding change in the emc of the wood.

4.4 Physical Elements of Drying

The main reason for using heat in drying is to provide the energy required to evaporate the moisture present in the wood, 1,000 Btu or more being required to evaporate each pound [2.25 MJ (megajoules) per kg] of water present. An additional reason, however, is to raise the temperature of the lumber, since the movement of moisture is more rapid at high temperatures. To produce the same rate of diffusion at 120°F as at 160°F (50°C and 70°C), a much lower humidity will be required and a steeper moisture gradient will result. Increased temperature, therefore, increases the rate of moisture movement, so that a high humidity may be maintained without unduly slowing the rate of drying.

Wet wood is more plastic at high temperatures and, because of this increased plasticity, it yields more readily to any stress imposed. However, whether wet or dry, wood is weaker at higher temperature. Wood may be more prone to checking and splitting at higher temperatures.

When the surface of lumber contains free water, the temperature of the wood is the same as that of the wet bulb and will stay at that temperature as long as there is sufficient moisture movement to keep the surface moist. When the free water at the surface is evaporated, the mc of the surface approaches the equilibrium moisture content (emc). Concurrently, the temperature of the wood surface increases and approaches the dry-bulb temperature.

To perform effective drying, a uniform movement of air is necessary to carry heat to lumber and to carry evaporated moisture away. This circulating air must pass over the

surface of the boards being dried. Any air that misses a pile of lumber accomplishes no drying.

Since the air is cooled and becomes wetter as it picks up moisture, its ability to dry the lumber becomes progressively less as it passes through a load. By increasing the air velocity, the lumber near the exit side of a load receives hotter, drier air than it otherwise would. Not only will this result in faster drying of the lumber at the exit side, increasing the average rate of drying and reducing the drying time, but it will also result in higher surface transfer rates and more uniform drying of a load. These advantages must be measured against the increased cost of power to attain the greater air velocities.

At the beginning of drying, a considerable amount of water is being evaporated and, as a result, the drop in air temperature across a load is very high, and the humidity of the air increases almost to the saturation point. Under these conditions, for rapid drying the air velocity should be high. On the other hand, when the surface of the lumber has been dried below the fsp, the rate of evaporation is reduced. Under these conditions, a much reduced air velocity is acceptable. For these reasons use of variable-speed fans could be advantageous.

4.5 Drying Defects

Drying procedures may result in defects that reduce the grade and value of the lumber being dried. Such losses are referred to as drying degrade. Some defects become obvious as they occur; the effect of others may not be realized until a later stage of manufacture is undertaken, but can be related directly to the seasoning procedure used. Some defects which appear during drying are, in fact, the result of other processes. They may be due to faulty procedures in earlier stages of manufacture or to the intrinsic properties of the wood. A kiln operator must select his drying procedures so as to maximize kiln throughput and, at the same time, minimize lumber degrade losses.

5.0 DESCRIPTION OF DRYING ALTERNATIVES

A kiln is a structure in which lumber is dried by circulation of air of controlled temperature and humidity. Various materials are used to build kilns. Wood, concrete block, clay tile, reinforced concrete, concrete asbestos panels, and insulated aluminum panels are all commonly used, with various vapor barriers to restrict vapor movement from inside the kiln, thereby keeping the structural materials dry.

Figure 3 illustrates a typical dry kiln.

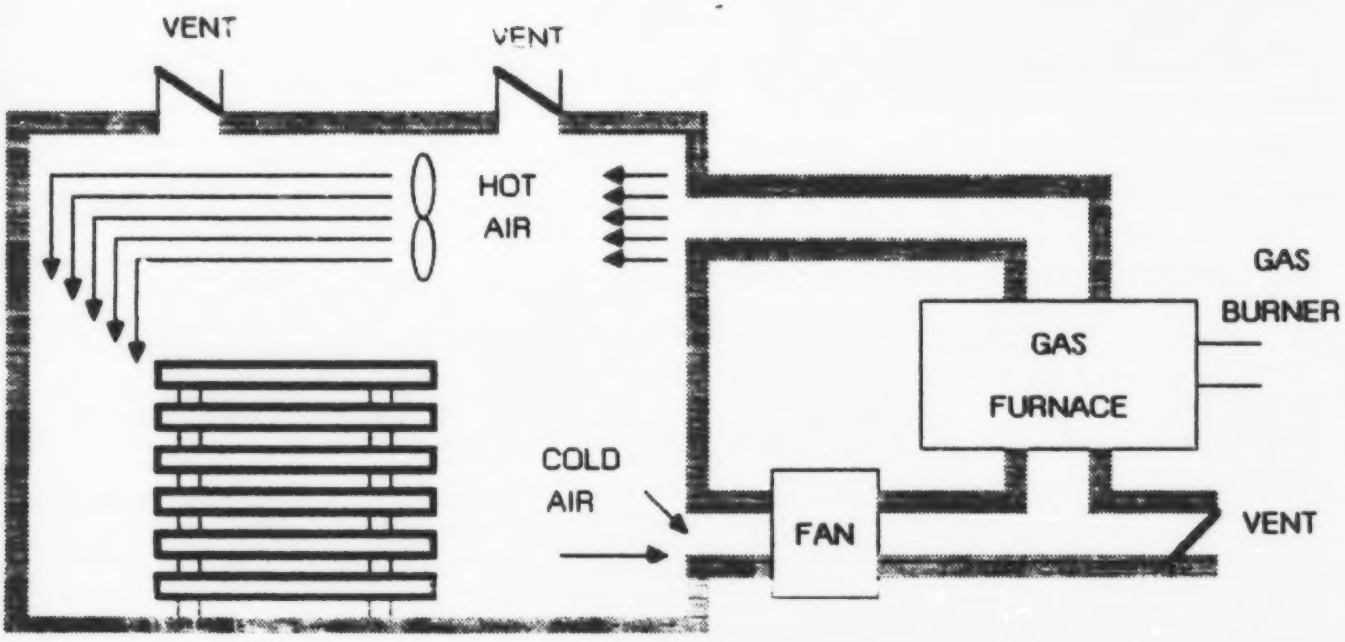


Figure 3 - Typical Hot Air Kiln

There are two methods for heating kiln air. One is called a hot air system where gas or oil are burned in an air heater and the hot combustion gases are mixed with the kiln air. The other is termed an indirect heating system where the temperature of kiln air is controlled by passing it over pipes containing a hot fluid (usually either steam or oil). In this study, kilns are divided into three groups according to the fuel that they use. These groups are:

(a) natural gas fired hot air;
(b) wood waste fired indirect heating;
(c) dehumidification.

There are some gas fired indirect systems and there are some direct fired wood waste systems so that the above three groups do not include all the kilns used but they do account for over 90% of them. The dehumidification type kiln in one sense is an indirect heating system in that the air is heated by passing it over a hot heat exchanger surface.

5.1 Natural Gas Fired Hot Air

This type of kiln is the most popular since approximately half the kilns in British Columbia are of this type. A hot air furnace (see Figure 3) along one of the walls takes in return moist air from the kiln via an air duct, heats it with a gas burner and discharges the air and products of combustion back

to the kiln by means of another duct. The air is circulated in the kiln itself by means of a series of fans located above each lumber pile. These fans are reversible and thus supply warm air to alternate sides of the lumber pile. If the pile is about 3 metres wide, the deepest point of air penetration is half-pile or 1½ meters.

Ventilation in these types of kilns is necessary, because as the lumber dries the moisture is transferred to the air and, in order to maintain the humidity low enough so that drying will occur at a reasonable rate moist air has to be vented to atmosphere. This is achieved by openings in the roof and return air duct or ducts. As the humidity rises above a certain set point these vents are opened. Some of them exhaust hot moist air while others bring in cold fresh air.

The advantages of gas kilns are ease of operation and speed of drying. For instance, spruce pine fir dimension lumber can be dried at a fast rate without incurring much degrade. Therefore, it pays to fire the kiln at a high rate, processing a large quantity of lumber through a relatively small kiln.

5.2 Wood Waste Fired Indirect Heating

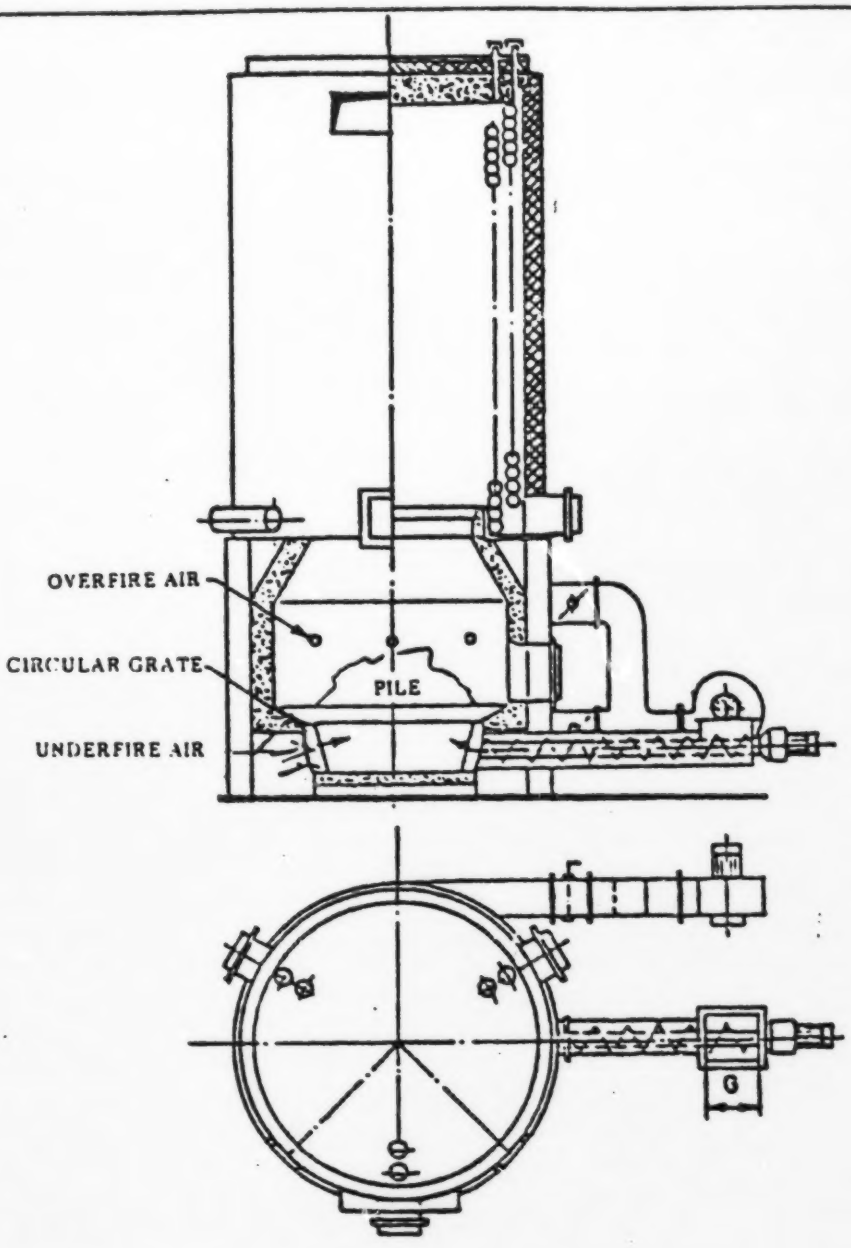
In this system, bark and shavings are burned in a separate combustor. Figure 4 illustrates a typical combustor. Fuel is fed under the piles by a screw while overfire air is added above the pile and the combustion is completed in the upper part of the furnace. The upper part of the furnace is lined with oil filled tubes for heat transfer. The hot oil can then be pumped to one or several kilns depending on the size of the kilns and the size of the combustor. The thermal oil is then circulated through the kiln or kilns at a low pressure and at a temperature of 450°F to 500°F. A schematic of a complete system is shown in Figure 5. There are several companies offering this type of system. Three of the more popular ones are Konus Kessel, Volcano and Lamb-Cargate.

5.3 Dehumidification

Figure 6 is a schematic of a dehumidifier type kiln. In this process, warm moist air from the drying chamber or kiln is forced over the cold evaporator coils in the dehumidification unit. The moisture in the air condenses on the coils and the water is drained from the system. The sensible heat removed from the air and the latent heat of condensation cause the refrigerant fluid in the evaporator to vaporize. The heated refrigerant vapor is then cycled through the compressor where it absorbs some additional heat energy equivalent to the work input of the compressor.

As a hot gas at high pressure, the refrigerant passes through the condensor, at which point the acquired heat is transferred back to the "dry" kiln air coming from the evaporator, and the

refrigerant reverts to the liquid state. In this manner, heat is recycled, whereas in conventional kiln drying systems considerable heat is exhausted to the atmosphere through venting.



Konus – Kessel

Multiple Chamber Incinerator

FIGURE 4

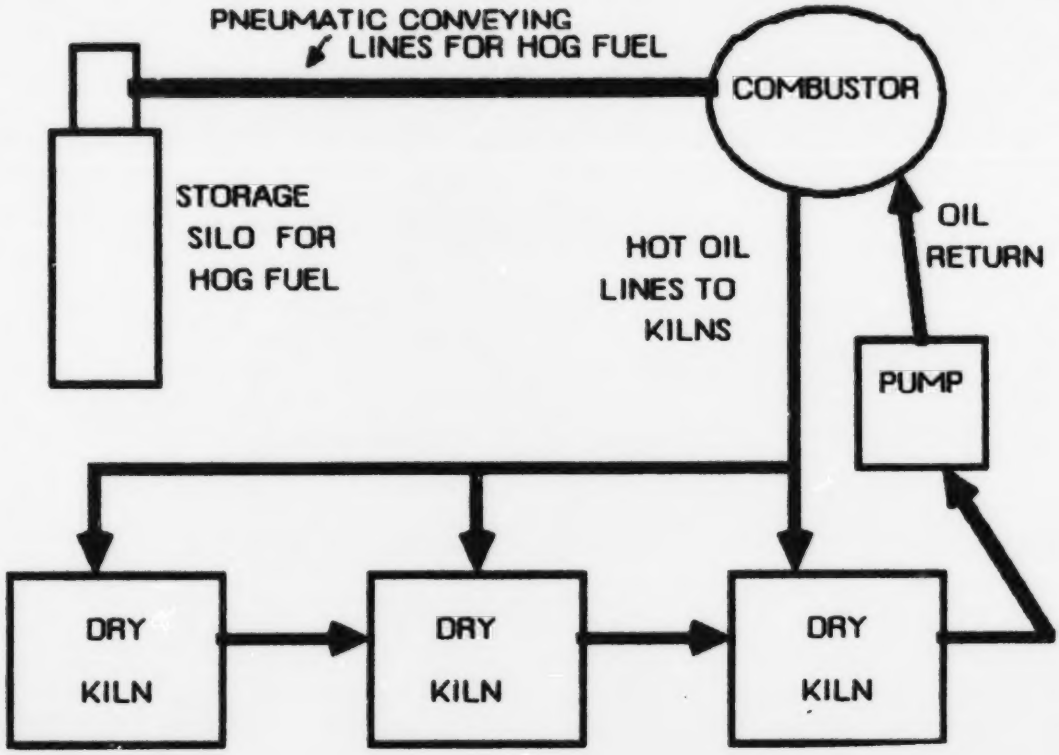


Figure 5 - Wood Waste Drying System

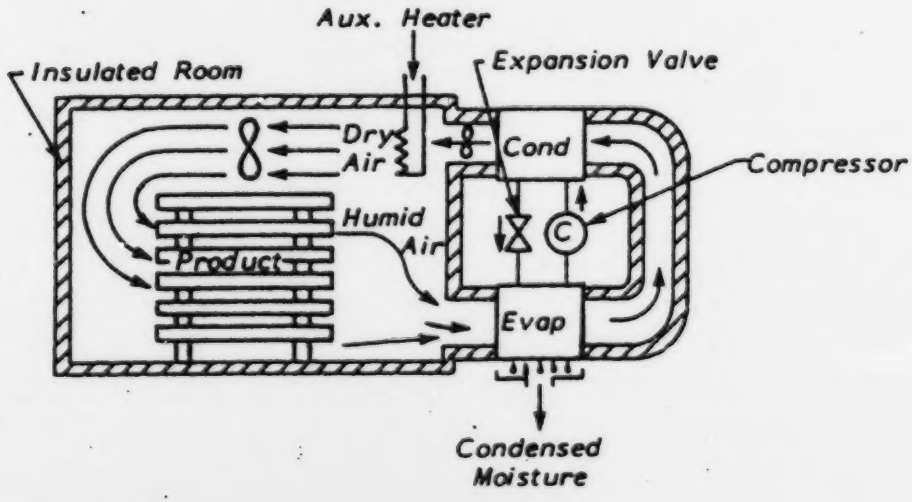


Figure 6 - Dehumidification Kiln

In addition to the energy input of the compressor, the dehumidification system utilizes an electrical resistance heater for a few hours at the beginning of each run to bring the temperature up to an effective operating level of approximately 75°F (24°C).

6.0 ENERGY CONSUMPTION

6.1 Test Results

Appendix I contains the results of a comparison test between a dehumidifier kiln and a natural gas fired kiln. Two similar charges of western hemlock clears were used with one going to a dehumidifier kiln and the other one going to a gas fired kiln. The energy consumption for both kilns was measured during the drying cycle with the results as follows:

TABLE 2 - Drying Test Results

	Dehumidifier Kiln	Gas Fired Kiln
Electricity Consumption kW.h/Mfbm	475	72
Electricity Rate $/kW.h	.045	.045
Electricity Costs $/Mfbm	21.38	3.24
Gas Consumption GJ/Mfbm (kW.h/Mfbm)	-	3.80 (1057)
Gas Rate $/GJ ($/kW.h)	-	4.14 (.015)
Gas Cost $/Mfbm	-	15.75
Total Energy kW.h/Mfbm	475	1,129
Total Energy Cost $/Mfbm	21.38	18.99

% Elect - 6.4

6.2 Comments on Results

On an energy basis, the dehumidifier kiln used only 42% of the energy used in the gas kiln. The energy costs were slightly higher for the dehumidifier because the gas rate is one-third of the electric rate.

It should be noted that the gas fired kiln used was a relatively efficient one compared to gas kilns in general and was operated at close to optimum conditions. But, per Forintec comments, modifications should be made to the dehumidifier kiln which could improve its energy efficiency by 10%. Also, in the dehumidification process the lumber was dried to a far greater extent than was necessary and if closer

monitoring was employed the energy efficiency could be improved by another 10%.

6.3 Wood Waste System

The above comparison tests did not include a wood waste fired system because essentially the energy consumption in the kiln itself would be the same as for a gas-fired kiln. Accordingly, the energy consumption data for a wood waste system is projected to be as follows.

TABLE 3 - Wood Waste Energy Costs

	Wood Waste System (Assume Konus Kessel)
Nominal Input to Kiln (GJ/Mfbm (kW.h/Mfbm)	3.80 (1,057)
Fuel Input to Combustor GJ/Mfbm (kW.h/Mfbm) (assume 60% efficiency)	6.33 (1,759)
Unit Cost of Waste Wood $/GJ	1.20
Cost of Waste Wood	7.60
Electricity for Fuel Handling kW.h/Mfbm (ref 4)	21
Electricity for Fans kW.h/Mfbm	72
Electricity Rate $/kW.h	.045
Electricity Cost $/Mfbm	4.19
Total Energy Cost $/Mfbm	11.79

6.4 Other Fuels

Butane, propane and oil are also used in hot air kilns. For the purposes of this report, it is assumed that the kiln energy efficiency for each of these fuels is the same as gas.

Figure 7 is a comparison of the energy cost for the various fuels based on the test results and assuming western hemlock clears as the lumber being dried.

The energy values for all the fossil fuel types are based on the energy consumption of the Kelfor kiln during the comparison tests while the dehumidification figures are based on the energy consumption of the Norsecraft kiln reduced by 10.00% to account for the overdrying that was done during the Norsecraft test.

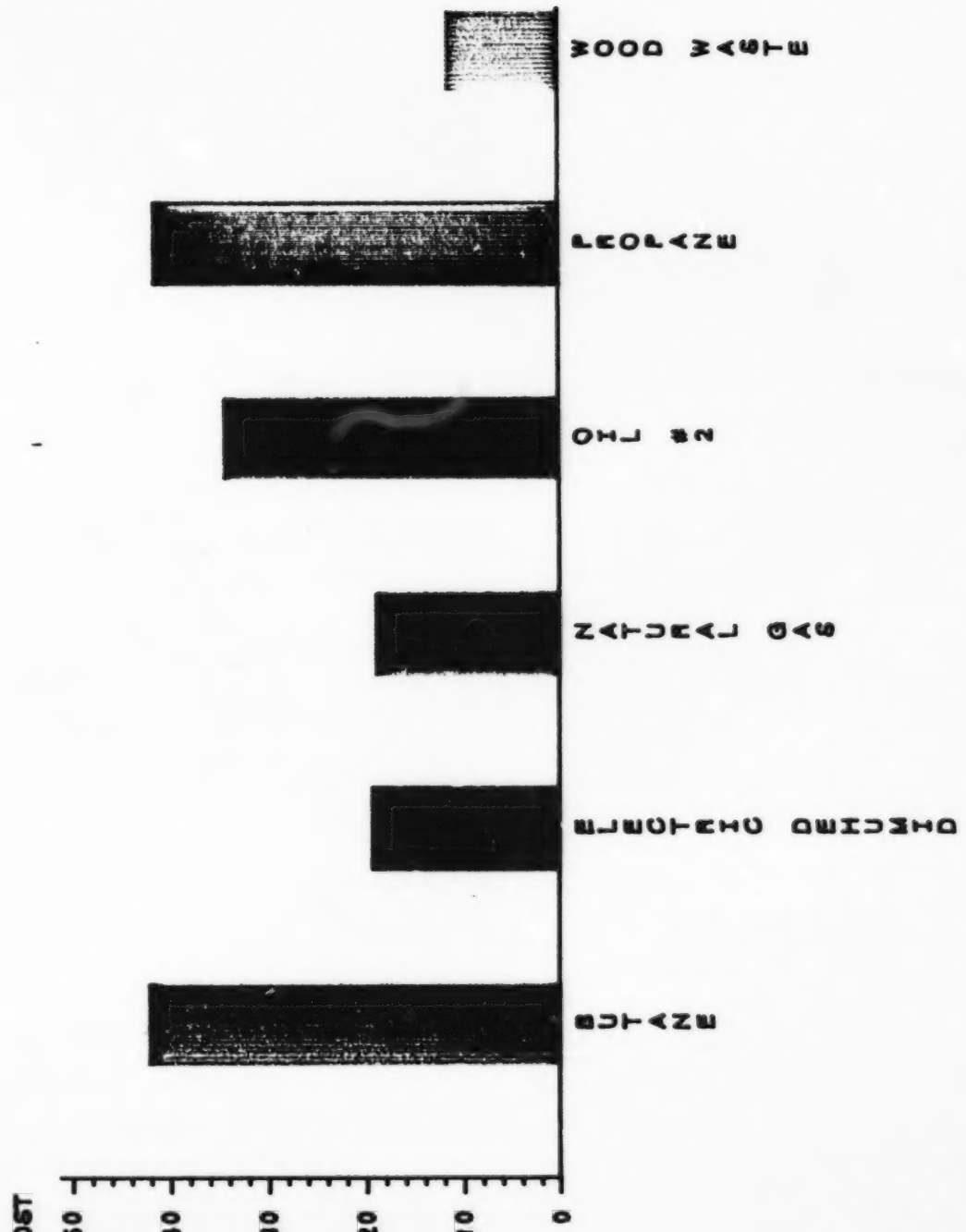


Figure 7 - Energy Cost in $/MFBM

7.0 CAPITAL COST

The main variables which affect the capital cost of a drying system are the following:

- size of system;
- species to be dried;
- end product (construction grade or remanufacturing product).

In this report, the species was taken to be western hemlock, and the economics were calculated on two different size systems. These costs are based on preliminary budget figures only.

7.1 Small System

Nominal Kiln Capacity - 75,000 fbm

Annual Kiln Volume - 2.5 million fbm

Dehumidification Unit - $250,000* - Aluminum Structure
- 200,000* - Wooden Structure

Hot Air Kiln (Natural Gas, Oil, Propane, Butane) - $250,000* - Aluminum

* Based on phone conversations with Euraken and Salton Fabrication Ltd.

For the small systems the wood waste units are not practical and the manufacturers of such units are not marketing them as being suitable for small operations.

7.2 Large System

It wasn't feasible to exhaustively compare the capital cost of the three alternatives. However, Salton Fabrication Ltd. who market all three alternatives (wood waste, gas and dehumidification), did a fairly exhaustive analysis for a particular company drying western hemlock. The results are as follows:

Annual Lumber Drying Volume - 36 million fbm

No. of Kilns	- 5
Kiln Construction	- Prefabricated Aluminum
Capacity of Each Kiln	- 200,000 fbm
Species	- Coastal Hemlock

TABLE 4 - Capital Cost Comparisons

Wood Waste	Dehumidification	Gas Fired
Heating Capacity - 30 MM Btu (total)	Compressor Capacity - 300 hp/kiln	Heating Capacity - 6 MM Btu/kiln
Heat Transfer Medium - Oil		
Capital Cost - $3 Million	$2.5 Million (Wood Structures)	$2.2 Million
Cost/fbm - $3	$2.5	$2.20

Note: The design for all three systems was based on the same drying time.

8.0 OPERATING AND MAINTENANCE COSTS

The operating and maintenance (O&M) costs are based on data given in reference 3. If the O&M costs for a hot air kiln (using natural gas, oil, butane or propane) are taken as a base, the additional costs to operate a wood waste system is as follows:

Additional Labour Requirements	- 300 hours/year
Labour Cost	- $20/hour
Annual Labour Cost	- $6,000/year
Annual Lumber Drying Volume	- 36 million fbm
Additional Labour Cost	- $.17/Mfbm
Maintenance	- 5% of additional capital cost
Additional Capital Cost	- $800,000
Annual Additional Maintenance	- $40,000/year
Additional Maintenance Cost	- $1.11/Mfbm

A dehumidifier kiln would have approximately the same operating and maintenance costs as a gas fired kiln.

9.0 SIZING QUALITY

As mentioned previously, the process of drying does damage a certain percentage of the lumber being dried. This damage (degrade) occurs as obvious defects (checks, splits, etc.) or as internal stresses which cause problems during later stages of manufacture. During the comparison test, it was not possible to quantify accurately the difference in degrade between the dehumidification drier and the gas-fired drier because to do so

would require monitoring the test charges of lumber at several stages of manufacture. This will be done in the upcoming CEA project (reference 5). However, there was a qualitative evaluation made. The most significant difference between the kilns was that the dehumidification dried lumber contained far less internal stress than the gas kiln dried lumber. This would mean a less degrade at a later manufacturing stage.

Drying degrade ranges from 5 to 25% and is the most significant cost in drying with respect to clears, quality lumber used for added value products (furniture, panelling, doors, etc.). The reduction in degrade, due to dehumidification drying, has not been quantified but, per discussions with Forintec, it would seem reasonable to expect at least a reduction in degrade of 5 percentage points.

10.0 ECONOMIC COMPARISON BETWEEN ALTERNATIVES

10.1 New Kilns

Tables 5 & 6 and Figure 1 show the savings and good economies of electric dehumidification drying of western hemlock clears in new kilns. The economic relative advantages of dehumidification drying for other species are believed to be of the same order, but the absolute drying costs will be different. Drying costs for western hemlock clears using the various fuels and systems are summarized below:

Fuel - System		Small System $/Mfbm	Small System % of Highest	Large System $/Mfbm	Large System % of Highest
Electric	dehumidification	70	69	68	69
N. Gas	hot air	77	76	75	76
Oil	hot air	93	92	91	92
Butane	hot air	101	100	99	100
Propane	hot air	100	99	98	99
Wood Waste	hot air	*		72	73

* Not economical at this time.

10.2 New Kilns and Conversions in Propane/Oil Areas

For areas where only propane, butane, or oil is available, drying lumber is a very expensive process.

It is anticipated that the use of dehumidification will increase the amount of drying and in some cases replace existing propane/oil systems.

TABLE 5 - Overall Economic Comparison
Between Drying Alternatives - Small System

Small Size Plant: 75,000 fbm kiln capacity Annual Volume in million fbm: 2.50

Lumber Species: Western Hemlock Value of Dried Product: 450.00 $/Mfbm

	Electric Dehumid.	N. Gas Hot Air	Oil Hot Air	Butane Hot Air	Propane Hot Air
Energy Cost $/Mfbm (see note 1)	19.24	18.99	34.46	42.29	41.69
Capital Cost Inst $	280,000.00 (note 2)	250,000.00	250,000.00	250,000.00	250,000.00
Annual Cost Capital Charges (see note 3)	37,486.06	33,469.70	33,469.70	33,469.70	33,469.70
Annual Capital Charges $/Mfbm	14.99	13.39	13.39	13.39	13.39
Percent Degrade Loss (including loss at remanufacturing stage)	8.00	10.00	10.00	10.00	10.00
Value of Degrade Loss $/Mfbm	36.00	45.00	45.00	45.00	45.00
Drying Costs Excluding Degrade	34.24	32.38	47.85	55.68	55.08
Total Cost of Drying $/Mfbm (see note 4)	70.24	77.38	92.85	100.68	100.08

NOTES:

1. The energy values for all the fossil fuel types are based on the energy consumption of the Kelfor kiln during the comparison tests while the dehumidification figures are based on the energy consumption of the Norsecraft kiln reduced by 10.00%.

2. The capital cost of the dehumidifier kiln is based on a wood structure building that is 40.00% larger than the gas fired kiln. It also assumes that an equal size wood structure kiln would cost $200,000.00 compared to the $250,000 of an aluminum building.

3. This calculation uses a capital recovery factor of 0.13388 which assumes an interest of 12.00% and a period of 20.00 years.

4. This total cost of drying does not include the costs of operating labour and maintenance since these costs are judged to be relatively equal for all the alternatives.

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TABLE 6 - Overall Economic Comparison
Between Drying Alternatives - Large System

Large Size Plant: 1,000,000 fbm kiln capacity Annual Volume in million fbm: 36.00

Lumber Species: Western Hemlock Value of Dried Product: 450.00 $/Mfbm

	Electric Dehumid	N. Gas Hot Air	Oil Hot Air	Butane Hot Air	Propane Hot Air	Wood Waste Hot Air
Energy Cost $/Mfbm (see note 1)	19.24	18.99	34.46	42.29	41.69	11.70
Capital Cost Inst $ (see note 2)	2,500,000	2,200,000	2,200,000	2,200,000	2,200,000	3,000,000
Annual Cost Capital Charges $ (see note 3)	334,696.95	294,533.32	294,533.32	294,533.32	294,533.32	401,636.34
Annual Capital Charges $/Mfbm	9.30	8.18	8.18	8.18	8.18	11.16
Percent Degrade Loss	8.00	10.00	10.00	10.00	10.00	10.00
Value of Degrade Loss $/Mfbm	36.00	45.00	45.00	45.00	45.00	45.00
Ann Maint Insur Costs $ (see note 4)	125,000.00	110,000.00	110,000.00	110,000.00	110,000.00	150,000.00
Maint Insur Costs $/Mfbm	3.47	3.06	3.06	3.06	3.06	4.17
Cost Excluding Degrade Loss $/Mfbm	32.01	30.23	45.70	53.53	52.93	27.02
Total Cost of Drying $/Mfbm	68.01	75.23	90.70	98.53	97.93	72.02

NOTES:

1. The energy values for all the fossil fuel types are based on the energy consumption of the Kelfor kiln during the comparison tests while the dehumidification figures are based on the energy consumption of the Norsecraft kiln reduced by 10.00%.

2. The capital cost of the kiln systems was based on budget figures provided by Salton Fabrication Limited.

3. This calculation uses a capital recovery factor of 0.13388 which assumes an interest of 12.00% and a period of 20.00 years.

4. The maintenance, insurance costs are calculated at 5.00% of the equipment capital costs, a figure derived from reference 3.

For the smaller system, the wood waste alternative is not considered a practical alternative. Electricity with dehumidification is the lowest cost alternative not including the effect of degrade and, if a 2% improvement in degrade is considered, it is significantly less expensive than even natural gas. Observation of the table reveals that the dehumidification process is always the least expensive and becomes increasingly less expensive as the value of dried product increases and the percent of degrade is reduced.

For the larger system, the wood waste alternative is the least expensive if the effect of degrade is neglected. However, if only a 2% improvement in degrade is considered, the electric alternative is less expensive.

11.0 MARKETING POTENTIAL FOR B. C. HYDRO

Drying kilns in B. C. are a large energy consumer and due to the apparent economic benefits to the industry of using the dehumidification process, there is a potential electric market available to B. C. Hydro. Because the dehumidifier process is superior to the hot air method, particularly for added value product (furniture, doors, panelling, etc.) it is appropriate that B. C. Hydro market electricity for this application. Doing so would not have a significant impact on our gas revenue because the potential market involves either new kilns for the coastal lumber industry or a replacement of existing hot air kilns in the interior. The size of this market depends on the following factors:

- the number of present kilns using butane, propane and oil;
- increase in the percentage of lumber dried;
- financial health of lumber industry;
- promotion used;
- incentive electric rates.

The market potential for electricity within five years with promotion for dehumidification drying is estimated at $20 million annually. The $20 million revenue figure was estimated as follows:

New Kilns

Increase in drying coastal lumber	$8 million
Interior Spruce, Pine Fir market	$9.5 million
In Propane, Oil and Butane Areas	$2.5 million

This estimate is based on the three sets of assumptions described below:

11.1 Propane, Oil and Butane Fired Kilns

There is approximately 600 million fbm of lumber dried in B. C. by kilns that are fired with propane, oil or butane. They are all located in regions where gas is not available. It would be economically attractive for the companies involved to convert to dehumidification. In fact, in some cases it may make a present uneconomic operation profitable. Assuming that this lumber is SPF and would only require 184.6 kW.h/Mfbm of electricity for drying, if 50%* of this lumber was dried with dehumidification kilns, it would represent to B. C. Hydro an annual revenue of 2 1/2 million dollars at .045 $/kW.h.

11.2 Increase in Drying of Coastal Lumber

Forty percent of coastal lumber is western hemlock which is very difficult to dry with conventional hot air kilns. Unfortunately, the coastal lumber industry is finding it more and more difficult to market green hemlock at a profitable price. One solution is to develop markets for the clears or the quality lumber, and this is definitely feasible if the lumber is dried properly.

It appears that drying by dehumidification is the most suitable process for drying this material. Approximately 1600 million fbm of western hemlock lumber is produced annually. If 25%* of this lumber was marketed as dried clears, it would represent an annual revenue to B. C. Hydro of $8 million at .045 $/kW.h.

11.3 Interior Spruce, Pine, Fir (SPF) Market

It also appears that electricity with the dehumidification process is competitive with other fuels for the SPF dimension lumber market. Although for this market, the dehumidifier kiln does not have as great a cost advantage as in the above-mentioned area. However, if 20%* of this market was penetrated with electricity, it would represent to B. C. Hydro an annual revenue of $9.5 million at .045 $/kW.h.

* These market penetration estimates are preliminary, and are based on discussions with Forintek and COFI representatives.

12.0 RECOMMENDATIONS

It is recommended:

1. that the B. C. lumber industry investigate the economics of dehumidification drying, particularly with respect to processing western hemlock clears for the remanufacturing market and to replace oil, butane and propane fired kilns;

2. that BCH, possibly as a joint effort with COFI, conduct detailed market research to verify the potential of this technology with a view to identifying the best approach to its development.

13.0 REFERENCES

1. "Replacing Fossil Fuels With Sawmill Residues in B. C. Lumber Kilns", J.F.G. Mackay, R. W. Nielson, G. Bramhall, Forintek Canada Corporation, 1974.

2. "Kiln Drying of Western Canadian Lumber", G. Bramhall, R. W. Wellwood, Forintek Canada Corporation, 1976.

3. "A Study of the Basis for Comparing the Economics of Natural Gas and Wood Fuels in the Forest Products Industry", B. H. Levelton and Associates Ltd., 1981.

4. Letter from QM Industries Ltd. - "Electrical Load - Thermal Oil Konus Systems", 21 September 1984.

5. "Heat Pump/Dehumidifier Kilns Drying Softwood Lumber" - CEA Project 418 U 461, 1985.

6. "Comparison of a Conventional Kiln to a Uraken Dehumidifier - Heat Pump Lumber Dryer", B. W. Comis, British Columbia Forest Products, May 1981.

7. "Conversion Factors for the Forest Products Industry in Western Canada", J. Dobie, D. M. Wright, May 1972.

APPENDIX 1

Lumber Drying Project

Lumber Drying Project Co-Sponsored by B. C. Hydro, COFI and Forintec

Dehumidifer Kiln

Species - Western Hemlock
2 x 3 inch stock

Consumption in kW.h — Multiplier equals - 160.000

	Meter Reading 5 March	Meter Reading 23 March	Consumption kW.h
Heat Pump Circuit	784.000	887.000	16480.000
Resist. Heat. Circuit	396.000	407.000	1760.000
Total Cons.			18240.000
Elect. Rate $		0.045	
Elect. Cost		820.800	
Lumber dried fbm		38400.000	
Consumpt. in kW.h/Mfmb		475.000	
Cons. Million Btu's/Mfbm		1.621	
Elect. Cost per Mfbm in $		21.375	
Elect. Cost $/cu.m		9.059	

Load Factor

No. of days in drying cycle	19.000
No. of hours in drying cycle	456.000
Peak demand of resist. heater circ. kW	99.200
Cap. of compressor hp	
Peak demand of heat pump circ. kw	43.200
Load factor of resist. heat. circ. %	3.891
Load factor of heat pump circ. %	83.658

Gas-Fired Kiln

Species - Western Hemlock
2 x 3 inch stock

Natural Gas Energy — Meter Multiplier is - 1.321

	Start Reading	End Reading
Consumption (100 cu ft increments)	94222.000	98123.000
Heating value of gas Btu/cubic ft		1050.000
Consumption in million Btu's		541.088
Consumption in GJ		570.848
Consumption in million Btu's per Mfbm		3.606
Consumption in GJ/Mfbm		3.804
Cost per GJ in $		4.140
Total gas cost $		2363.312
Lumber dried Mfbm		150.071
Gas cost per Mfbm		15.748

Electric Cost

	Start Reading	End Reading	Difference
Consumption kW.h	0.000	10799.800	10799.800
Elect. consumption kW.h/Mfbm		71.965	
Elect. cost $/kW.h		0.045	
Total elect. cost $		485.991	
Elect. cost $/Mfbm		3.238	
Elect. capacity in kW		50.000	
Hours of operation		220.000	
Load factor elect. equip.		98.180	
Total cost $		2849.303	
Total energy cost $/Mfbm		18.986	
Total energy cost $/cu m		8.046	

APPENDIX II

INVITATION TO SUBMIT A RESEARCH PROPOSAL
ON SUBJECT 418 U 461

The Canadian Electrical Association invites the submission of proposals to do research work on the following:

TITLE

Evaluating the Applicability of Heat Pump/Dehumidifier Kilns for Drying Softwood Lumber

INTRODUCTION

Heat pump dehumdifiers have gained wide acceptance in eastern Canada and the U.S. for kiln drying hardwood lumber. There are relatively few installations in Canada almost all of which are drying specialty products. But, the construction grades of softwood lumber comprise the greatest proportion of total lumber dried and there are indications that there would be some advantages to using dehumidifier kilns for this type of lumber.

For instance, some preliminary testing of softwoods has shown that dehumidification drying would reduce the defects caused by drying and use less energy. However, a high (relative to hardwoods) moisture extraction rate is possible with softwoods and this can be taken advantage of in conventional kilns by using high temperatures to reduce the drying times. The economics of dehumidification drying are difficult to quanitify because of the lack of good test data. Wider use of this technology may not occur, or will be slow to develop, without demonstrations by means of well designed and conducted drying tests by a recognized independent authority.

POTENTIAL BENEFITS

This type of drying has the potential for:

- reducing consumption of fossil fuels and decreasing the total energy cost to the lumber industry;
- increasing the drying quality and minimizing lumber wastage;
- providing additional markets for electricity.

PROJECT OBJECTIVE

The CEA would like to promote the use of dehumidifiers for use in softwood lumber drying. The purpose of this project is to demonstrate the performance of dehumidifier kilns, compared to conventional kilns, in terms of recognized industry standards:

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a) energy consumption and the resulting effect on drying cost;
b) drying times;
c) quality of dried product and quantity of wasted lumber;
d) labour and maintenance costs;
e) capital costs;
f) lumber requirements.

STUDY PROCEDURE

A test kiln will be constructed (minimum capacity - 10 Mfbm) or, an existing kiln modified, in such a manner that it can be used as a conventional natural gas fired kiln or as a dehumidifier kiln. A test procedure will be developed for several of the most important species of softwood lumber.

In addition to a project report and the test procedures, the test results will be made available to the CEA and arrangements will be made for future CEA use of the test facility.

PROPOSAL GUIDELINES

It is anticipated that proposers shall co-fund the project substantially, that is, at least 25% of the total project funds shall be provided by the eventual contractor.

The CEA are prepared to support a substantial portion of the cost, provided the total requirements for funds over the life of the project do not exceed $160,000

BUDGET AND SCHEDULE

Constructions of Test Kilns (or modification of existing kiln)	3 months
Drying Tests	1 year
Results Analyzed & Report Preparation	2 months

The total budget over 1½ years is expected to be $200,000 to $250,000.

REFERENCES

1. Canadian Electrical Association - "State of the Art Heat Pump Studies 1978 - 1982", December 1983.

SUBMISSION OF PROPOSAL

The proposal, constituting an offer of services, is to remain valid upon acceptance by CEA during a period of one hundred twenty (120) days from the submission date. It must be properly completed and executed, in accordance with CEA's "Information and Standard Requirements for Guidance of Contractors Preparing a Proposal for CEA", issue May 1984. Six (6) copies are to be provided.

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CLOSING DATE FOR RECEIPT OF PROPOSALS: 4:00 p.m. Montreal Time
Thursday, September 20, 1984

The envelope shall be addressed to: Canadian Electrical Association
Suite 580, One Westmount Square
Montreal, Québec H3Z 2P9
Att: Director of Research & Development

and marked on the outside front:

PROPOSAL 418 U 461 - SEPTEMBER 20, 1984 , TO BE OPENED IN RESEARCH & DEVELOPMENT DEPARTMENT ONLY.